8/15/88

NOTE TO: John Knodel, Air and Toxics Div., ARBR-ARCP
Region 7

FROM: John Schakenbach, Project Officer JTS
Office of Program Development, ANR-445

Lewis Paley recommended you as a potential EPA reviewer of the enclosed draft CEM report by PEI. I would much appreciate whatever comments you can provide by August 24, as the final report must be completed by September 15. Comments may be E-mailed to me at EPA6100. My phone #: FTS 475-8545. Thanks.

JK

CEMS

Tony
John K
Pat

STAR CEM PROJECT
Issues Associated With The Expanded
Use of CEM's For Potential Acid Rain
Emissions Reduction Initiatives

cc's of
Hq + Industry
responses to Ex's

by

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April 1988

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SECTION 1

INTRODUCTION

As a part of the State Acid Rain (STAR) Program, the U.S. Environmental Protection Agency's (EPA's) Office of Program Development is evaluating a wide variety of issues that could confront State program managers if they were faced with the task of implementing acid rain legislation. One area of particular interest is the possible increased use of continuous emission monitors (CEM's) to measure compliance in an acid rain control program. CEM's are being mentioned frequently in various legislation approaches to acid rain control.

This project on CEM's stems from the second National STAR Program Workshop held in Asheville, North Carolina, in October 1986. At this workshop, participants from State air program offices discussed major problems encountered in managing both "total emission" and "emission rate" approaches to an acid rain control program. One major operational issue dealt with the role of CEM's. Because states have little or no experience with dynamic management of emissions to meet either a state reduction target or a statewide emission rate, no census emerged on how to handle these problems. The purpose of this project is to focus on identifying and seeking resolution to some of the uncertainties and problems related to expanded use of CEM's for acid rain control programs. Emphasis is placed on CEM's for SO_2 and NO_x, although data were also gathered on opacity monitors for particulate control.

Section 2 of this report presents an overview of the numbers and types of CEM's being used in the United States, the state of the art of CEM technology, and information on process improvements that CEM's can provide. A comparison of U.S. and foreign approaches to the use of CEM's is also provided. Obstacles associated with current use CEM Systems that would affect their expanded use in an acid rain program are also identified. Section 3 presents an evaluation of the potential for expanded use of CEM's for acid rain control programs based on interviews with equipment vendors, utility and industrial users of CEM's, and State and EPA Regional Office personnel. The views of each of these groups are compared and contrasted in the assessment of the potential for expanded use of CEM's. Section 4 contains conclusions on expanded use of CEM's based on the results of the study. An appendix contains a full report of the data provided by CEM vendors for assessing the state of the art for CEM's.

SECTION 2

CEM TECHNOLOGY AND POLICY PERSPECTIVE

The application of continuous emission monitoring systems to measure the emissions from stationary sources has attracted much attention in industry and government. Regulations by the Federal, State, and local enforcement agencies have resulted in the relatively widespread use of CEM's in certain industries; however, some had previously used CEM's for process control. Table 2-1 lists the source categories that must use CEM systems under the New Source Performance Standards (NSPS). The EPA also requires the use of CEM systems through Prevention of Significant Deterioration (PSD), State Implementation Plans (SIP's) and National Emission Standards for Hazardous Air Pollutants (NESHAP's). As a result, many States have now adopted CEM requirements for existing sources and have revised SIP's to include CEM regulations.

May also be required as part of Consent Agreement or under Section 114 Order.

The number of CEM system installations has increased over the past few years. Tables 2-2 and 2-3 present a partial listing of operating CEM systems by State and EPA Region, respectively. These tables are based on data included in the Continuous Emission Monitoring (CEM) subset of the Compliance Data System (CDS), as of February 1988; they do not account for the total number of CEM's in operation across the Nation.

ie tapes

The EPA and State monitoring regulations primarily require the monitoring of opacity, sulfur dioxide (SO_2), and nitrous oxides (NO_x) emissions. Some sources also may be required to monitor total reduced sulfur (TRS), carbon monoxide (CO), hydrogen sulfide (H_2S), carbon dioxide (CO_2), and

HCL monitors becoming more popular on hazardous waste incinerators.

Coal sampling data also collected and put in system.

TABLE 2-1. SUMMARY OF NSPS CONTINUOUS EMISSION MONITORING REQUIREMENTS

FOCUS on SO_2/NO_x/other S "CEMS?"

Source category	Affected facility	CEM type
Subpart D - Fossil-fuel-fired steam generators for which construction is commenced after August 17, 1971	Fossil-fuel and fossil-fuel/wood residue fired generators with capacity >250 million Btu/h (73 MW)	SO_2, NO_x Opacity, and O_2 or CO_2
Subpart Da - Electric utility steam generating units for which construction commenced after September 18, 1978	Fossil-fuel, fossil-fuel/mixed fuel, and combined cycle gas turbines with capacity >250 million Btu/h (73 MW)	SO_2, NO_x, Opacity, and O_2 or CO_2
Subpart Db - Industrial, commercial, institutional steam generating units	Steam generating units with capacity >100 million Btu/h (29 MW), petroleum refineries applicable under Subpart J, and incinerators applicable under Subpart E	SO_2, NO_x Opacity, and O_2 or CO_2
Subpart G - Nitric acid plants	Process equipment	NO_x
Subpart H - Sulfuric acid plants	Process equipment	SO_2
Subpart J - Petroleum refineries	Fluid catalytic cracking unit catalyst regenerator, fuel gas combustion, and Claus sulfur recovery plants with capacity >20 LT/D	CO, SO_2, H_2S, Opacity
Subpart P - Primary copper smelters	Dryer, roaster, smelting furnace, and copper converter	SO_2, Opacity
Subpart Q - Primary zinc smelters	Roaster and sintering machine	SO_2, Opacity

(continued)

(TABLE 2-1 continued)

Source category	Affected facility	CEM type
Subpart R - Primary lead smelters	Sintering machine, sintering machine discharge end, blast furnace, dross reverberatory furnace, electric smelting furnace, and converter	SO_2, Opacity
Subpart Z - Ferroalloy production facilities	Electric submerged-arc furnace	Opacity
Subpart AA - Steel Plants: electric arc furnaces constructed after October 21, 1874, and on or before August 17, 1983	Electric arc furnace	Opacity
Subpart AAa - Electric arc furnaces and argon-oxygen decarburization vessels constructed after August 7, 1983	Electric arc furnaces and argon-oxygen decarburization vessel	Opacity
Subpart BB - Kraft pulp mills	Recovery furnace, lime kiln, digester, brown stock washer, evaporator, oxidation, and stripper system	Opacity, total reduced sulfur (TRS)
Subpart HH - Lime manufacturing plants	Rotary lime kiln	Opacity
Subpart NN - Phosphate rock plants	Dryer, calciner, and grinder in a facility with production capabilities of >4 tons/h	Opacity
Subpart FFF - Flexible vinyl and urethane coating and printing	Rotogravure printing line with solvent-recovery control device	VOC
Subpart LLL - Onshore natural gas processing: SO_2 Emissions	Sweetening unit or sweetening unit with a sulfur recovery unit that has a design capacity of >2 LT/D H_2S in the acid gas	SO_2

TABLE 2-2. CONTINUOUS MONITORING SYSTEM FOR ALL SOURCES WITH OPERATING CEM SYSTEMS BY STATE

State	Total No. CEM systems	State	Total No. of CEM systems
Alaska	1	Mississippi	1
Alabama	10	Montana	1
Arkansas	6	North Carolina	7
Arizona	4	North Dakota	5
California	3	Nebraska	9
Colorado	7	New Hampshire	1
Delaware	2	New Jersey	3
Florida	23	New Mexico	5
Georgia	13	Nevada	4
Hawaii	1	New York	7
Iowa	21	Ohio	100*
Illinois	20	Oklahoma	8
Indiana	35	Pennsylvania	2
Kansas	12	Puerto Rico	1
Kentucky	9	South Carolina	8
Louisiana	17	Tennessee	12
Massachusetts	4	Texas	27
Maryland	1	Utah	2
Maine	3	Wisconsin	14
Michigan	34	West Virginia	2
Minnesota	10	Wyoming	7
Missouri	27		

* The Ohio EPA reported actual numbers of CEM's as 224. This includes 196 opacity, 21 gaseous emission, 5 vinyl chloride, and 2 H_2S monitoring systems.

Source: EPA Compliance Data System Quick Look Report, 2/12/88.

TABLE 2-3. CONTINUOUS MONITORING SYSTEM FOR ALL SOURCES WITH OPERATING CEM SYSTEMS BY EPA REGION

Region	Total No. of CEMS Systems
I	8
II	11
III	7
IV	87
V	213
VI	63
VII	69
VIII	22
IX	12
X	1

Update – MA

Source: EPA Compliance Data System Quick Look Report, 2/12/88.

oxygen (O_2). In 1975, the EPA promulgated comprehensive requirements for the CEM systems and laid down the minimum specifications with which the system should comply. These are discussed later in this section.

STATUS OF CEM'S IN THE UNITED STATES

- NO

Although the U.S. EPA has formulated guidelines on the use of CEM systems, decisions regarding actual enforcement and requirements are left to the States under the Clean Air Act. Moreover, the U.S. EPA requirements excluded those sources built or under construction prior to August 1971 and do not include all existing sources. ok The inclusion of existing sources is left up to the States. Because the program lacks a uniform national policy, it is perceived by many as being inherently inconsistent and unfair.

national guidance establishes minimum requirements. States may adopt more stringent requirements if desired. EPA, as part of its required oversight role can take enforcement at any time.

Soon after the introduction of CEM requirements and regulations, the EPA realized that many States had failed to comply with the CEM regulations and that those that had complied were not actively implementing or enforcing their CEM regulations (Quarles and Peeler 1986). In addition to policy issues, the EPA realized that several serious technical concerns were responsible for the States' reluctance to implement the CEM regulations. The technical concerns resulted from assumptions regarding the unreliability of CEM's, the burden of the operation and maintenance of CEM's, and the difficulty entailed in reviewing and interpreting reported data (Quarles and Peeler 1986). Since then, several studies have been made on the use of CEM systems, and most of the apprehensions have reportedly been resolved. Efforts by the CEM manufacturers, industrial users, and control Agencies, coupled with recent technical and methodological progress, are believed to have improved the technological feasibility and cost-effectiveness of CEM systems. As a

Because of structure of Regs

result, these systems are believed to give more reliable measurements and thus facilitate regulation and control of air pollution from stationary sources. Policy issues are still being discussed and debated, however.

The increased concern over the problem of acid rain has prompted the Agency to consider the use of CEM systems to determine continuous compliance with the standards for SO_2 and NO_x. Currently, data generated by CEM systems are used more as an indicator of compliance, than as a basis for checking compliance. The State of Pennsylvania recently implemented a program requiring facilities that have solid-fossil-fuel-fired combustion units with heat input capacities greater than 250 million Btu/h to monitor their opacity and SO_2 and NO_x emissions continuously. The data obtained from the CEM sytems are used to determine compliance with emission standards. The enforcement policy is based on the principle that uniform and reasonable compliance is expected, that significant violations will be penalized, and that corrective actions will be initiated for severe problems. Despite the success of the program in Pennsylvania, considerable apprehension about the use of CEM Systems for compliance purposes still exists in the industry and in some agencies. This apprehension seems to result from perceptions that the technology is still not fully mature, that it is prone to unreliable results, and that the Agency lacks a consistent and well-defined enforcement policy.

Fair statement for Appendix P & Subpart D's sources

in Pa or elsewhere

not in Region II, V, VII, IX, etc. 4/86

national policy on use of CEM data well defined.

STATE-OF-THE-ART CEM TECHNOLOGY

A wide range of CEM systems are manufactured and marketed in the United States. The gaseous emissions monitors use either extractive or in situ systems for analytical purposes. Extractive systems involve extraction, transportation, and analysis of the sample, while in-situ monitoring systems perform gas analysis as it exits the stack by different types of advanced spectroscopic methods.

The analytical techniques used in continuous source monitors encompass a wide range of chemical and physical methods. The chemical methods vary from basic coulometric titration to the measurement of light produced in chemiluminescent reaction. These systems use methods varying from the basic physics principles of light scattering to the more complex principles of detecting light absorption by second-derivative spectroscopy. Table 2-4 summarizes the principles of chemical physics currently used in marketed CEM systems. Although somewhat dated, the EPA Handbook "Continuous Air Pollution Source Monitoring Systems" (1979) gives comprehensive information on the various monitors and is the most current handbook on the subject available through the Agency.

Selection of a monitor depends on the EPA criteria for the Performance Specification Test. After its installation, a gaseous emissions monitor must meet specifications listed in Table 2-5. (published in CFR.) The EPA has documented the test procedures, but the Agency does not conduct any tests to certify the various brands available in the market. Table 2-6 summarizes the performance data obtained by contacting different CEM system vendors in the United States. The information presented in Tables 2-5 and 2-6 although reported in different format suggests that most monitors in the market appear to comply with the EPA performance specifications. Surveys and studies undertaken by the EPA (Quarles and Peeler 1986) indicate that CEM Systems are capable of performing reliably in the field. This is corroborated by the successful implementation of the CEM-based compliance program in Pennsylvania.

and elsewhere

up to 98% reliability

& do work >>90%? whenever S's are consistent

TABLE 2-4. PRINCIPLES USED IN EMISSION MONITORS

Opacity monitors	Gaseous emission monitors: Extractive systems	Gaseous emission monitors: In Situ systems
Visible light scattering and absorption	Absorption Spectroscopy Nondispersive infrared Differential absorption	Cross-Stack Differential absorption Gas-filter correlation
	Luminescence Methods Chemiluminescence (NO_x) Fluorescense (SO_2) Flame photometry	In-Stack Second-drerivative spectroscopy Electrocatalysis (O_2)
	Electroanalytical Methods Polarography Electrocatalysis (O_2) Amperometric Analysis Conductivity Paramagnetism (O_2)	

TABLE 2-5. REQUIREMENTS FOR SO_2 AND NO_x MONITORS

Parameter	Requirement
Accuracy	20%
Calibration error	5%
Zero drift (2-h and 24-h)	2% of span
Calibration drift (2-h and 24-h)	2.5% of span
Response time	15 min (max.)
Operational period	168 hours

TABLE 2-6. PERFORMANCE DATA OBTAINED FROM VENDOR SURVEY

Parameter	Requirement
Accuracy	± 1 percent
Calibration error	
Zero drift	0.5 to 1%/7 days
Span drift	1-4%/7 days
Response time	2-200 s
Operational period	
Repeatability	±0.2% of full scale

STATUS OF CEM SYSTEMS ABROAD

In the Federal Republic of Germany and Japan, CEM's are used extensively to ensure emissions compliance. Both of these countries (especially Japan) use a telemetric system where data are accessed by agencies via telecommunications links to monitor emissions; however, information on the systems and regulatory programs abroad is generally sparse. Germany has been basing compliance on a CEM system program for approximately two decades and has considerable experience in its implementation. The German program is considered herein in some detail to give a perspective on use of CEM systems for regulatory compliance.

State of the Art of Germany's Technology

The technology available in Germany is similar to that in the United States, and the German instruments operate on the same principles of physics as those listed in Table 2-4. Instruments must demonstrate the performance characteristics listed in Table 2-7 before they can obtain Federal agency approval for use. The performance characteristics are tested in a Federal "Suitability Test." Tables 2-5 and 2-7 show that the overall performance characteristics required here and in Germany are quite similar. Details on the vendors and the particular models offered in Germany can be obtained from the Federal Minister of the Interior, Germany (1985). Figure 2-1, which was prepared by the German EPA, Umweltbundesamt (UBA), shows the different types of monitors used to measure various pollutants in Germany.

CEM Program in Germany

BZ — • Hard wired controls to CEMS
• Maintenance/plant mgrs get fired

A complete description of the CEM System - based compliance monitoring program and the legal issues can be obtained in the Federal Minister of the Interior, Germany (1985). Figure 2-2 presents a schematic overview of the overall emissions measurement and monitoring program, whereas Figure 2-3

TABLE 2-7. PRINCIPAL PERFORMANCE CHARACTERISTICS AND THE MINIMUM REQUIREMENTS OF SUITABILITY TESTS FOR EMISSION-MEASURING INSTRUMENTS IN THE FEDERAL REPUBLIC OF GERMANY[a]

Performance characteristics	Minimum requirements
Reference quantity	Most sensitive indication range (full scale), $\bar{x}$
Analytical function	To be determined from reference measurements by means of regression analysis
Lower detection limit	2%
Reproducibility	To be determined from parallel measurements with two homogeneous instruments $R = \frac{\bar{x}}{u} \geq 30$ (in special cases: 50, 10) U is the uncertainty range
Zero point drift	±2% within the period of unattended operation
Sensitivity drift	±1 ... 4% within the period of unattended operation (Reference quantity: slope of the analytical function)
Availability	Three months operational test obligatory; specified 90%; 95% to be striven for
Interference error (response to stated levels of interfering substances present in the sample)	±4%
Period of unattended operation	To be determined from the suitabiilty test

[a] Nominal conditions of use under which the minimum requirements must be complied with are:

- Ambient air temperature
- Ambient air humidity
- Droplet content of the air
- Mains supply voltage
- Mechanical vibration
- Mechanical vibration

Source: Air Pollution Control Manual of Continuous Emission Monitoring, published by The Federal Minister of the Interior, 1985.

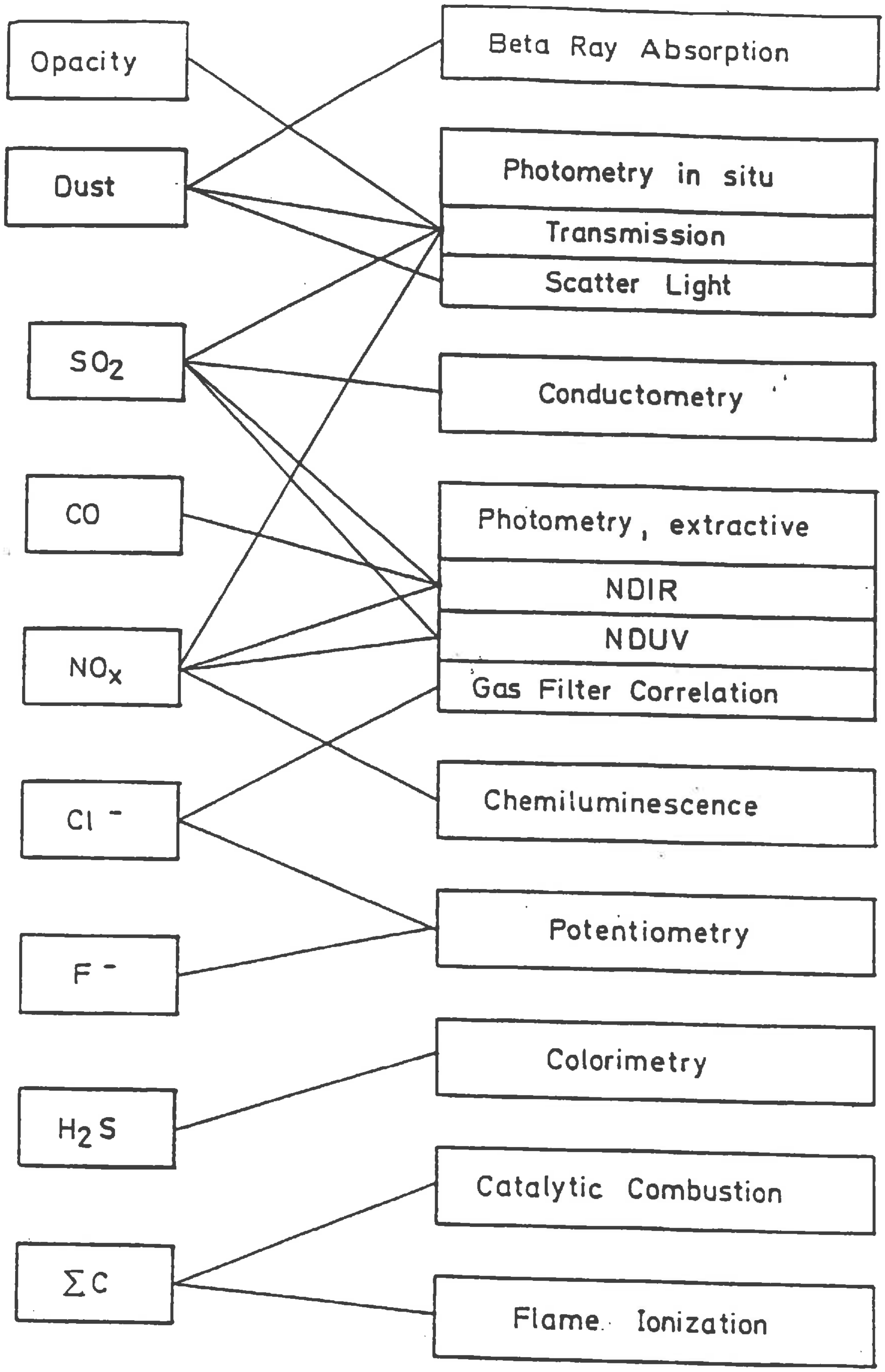

Figure 2-1. Monitor types used to measure gaseous pollutants in Germany (provided by UBA).

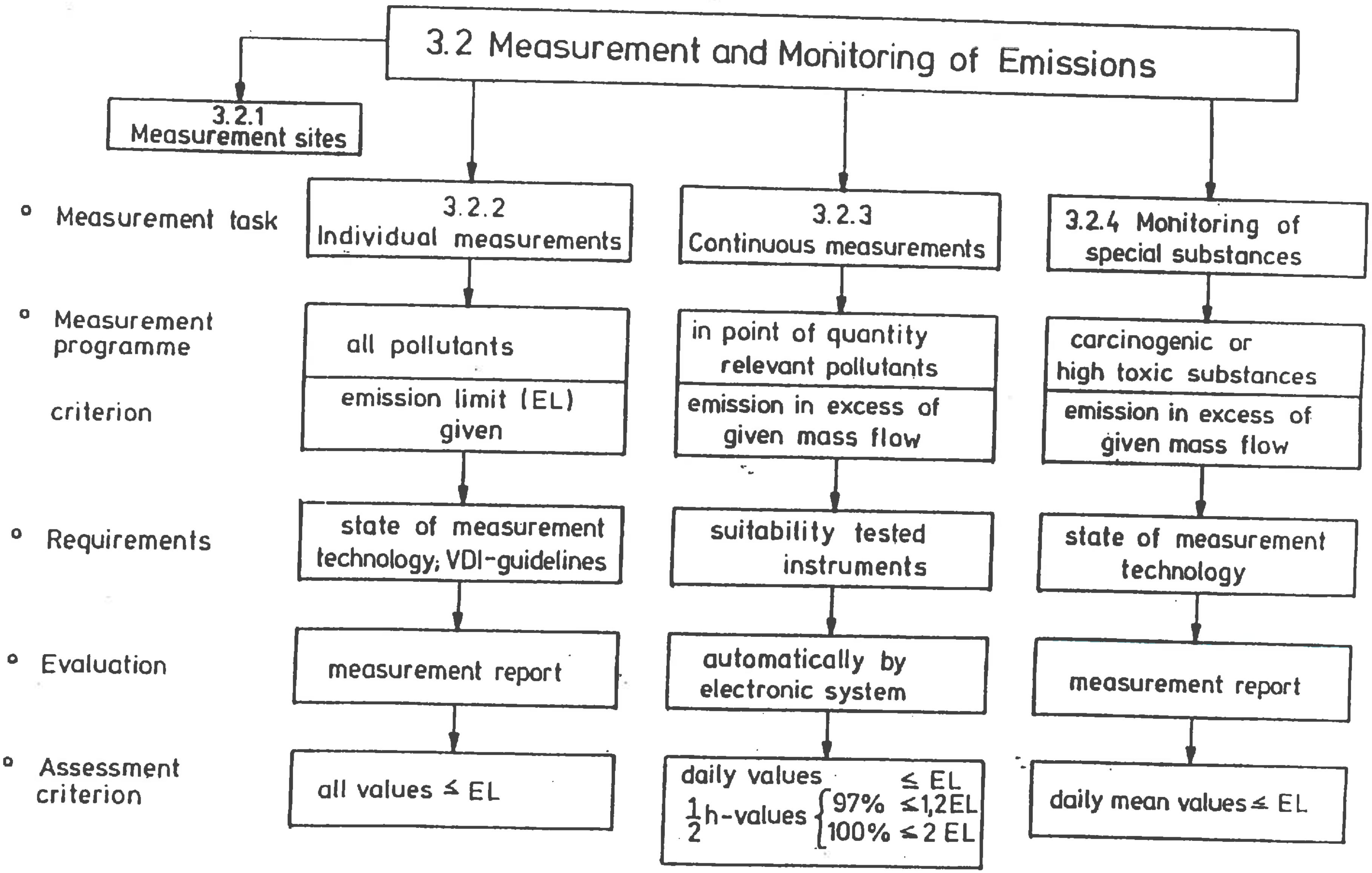

Figure 2-2. UBA overall emissions measurement and monitoring program overview.

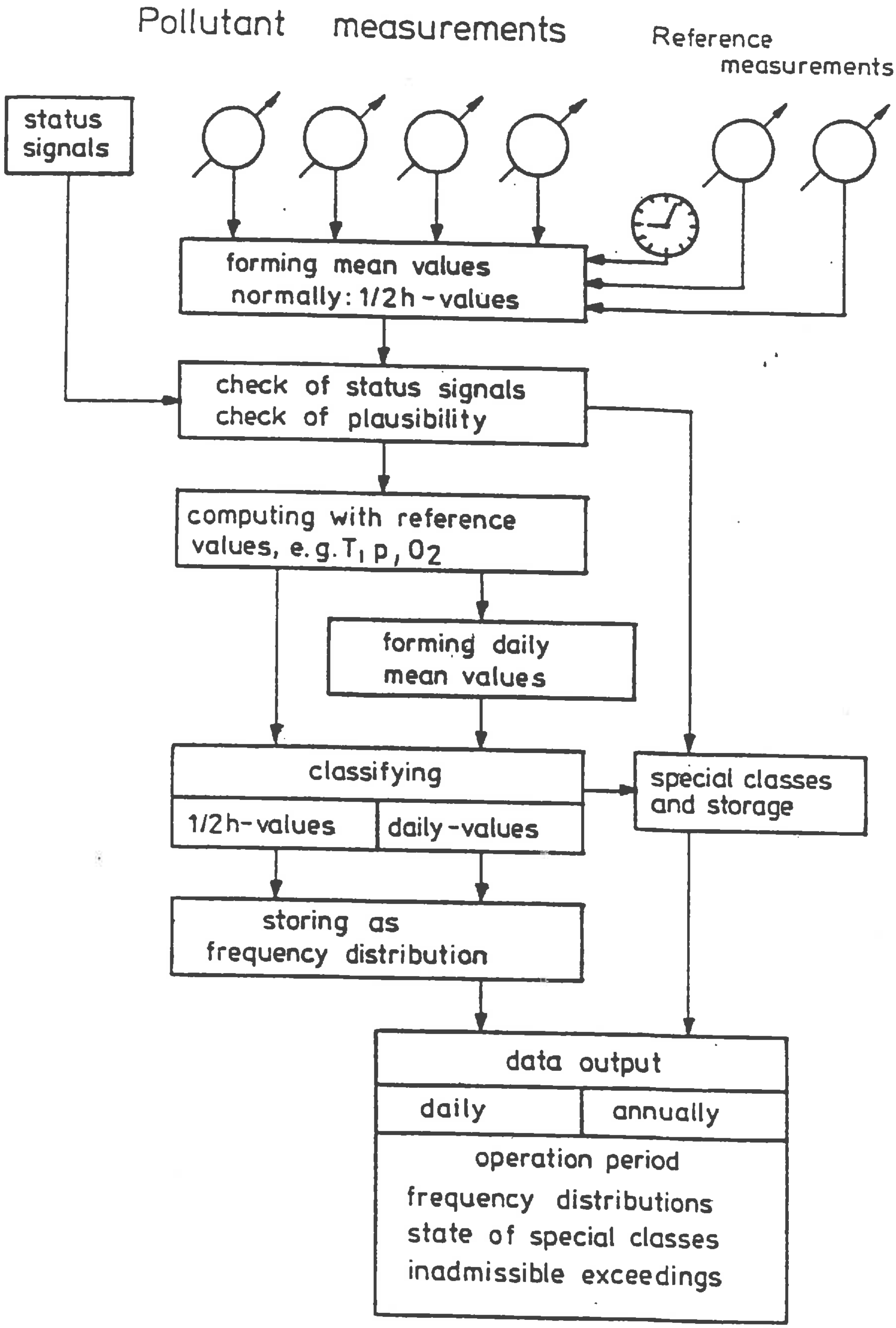

Figure 2-3. UBA pollutant measurement scheme overview.

presents an overview of the pollutant measurements scheme adopted in Germany. Although it is beyond the scope of this work to discuss the legal, policy, and technical issues of the German program, the salient features of the evaluation and assessment policies are presented here.

The evaluation consists of the following important steps:

- The raw data obtained from the instrument are used to compute the average value over a defined period of time--usually half an hour.

- The computed averages are converted into desired physical measuring quantities (mass or volume concentrations) by means of regression curves obtained during calibration.

- A plausibility check and several other status checks are made to ensure if the half-hour means are valid and representative. Only valid means are converted into the standard condition (273K, 1013 mbar) and related to the defined oxygen reference level.

- The standardized half-hour mean values are classified into various grades and stored as a frequency distribution. At least 20 grades should exist for such a classification, and the 10th grade should correspond to the emissions limit. Half-hour mean values falling within the confidence and/or tolerance ranges above the assessment thresholds are combined to form special grades.

- In parallel with the classification of the half-hour mean values, daily mean values are formed on the basis of the classifiable half-hour mean values. These are related to the daily operational time and stored as frequency distribution in three grades.

- At the end of a year, the supervising authority uses the record of the frequency distributions as the basis for assessing continuous compliance by source. An emission limit value is regarded to be in compliance if 1) all daily mean values are equal to or smaller than the emission limit value; 2) 97 percent of the half-hour mean values are equal to or smaller than 1.2 times the emission limit value; and 3) all half-hour mean values are equal to or smaller than twice the emission limit value.

CEM ENFORCEMENT POLICY IN THE UNITED STATES

Currently, the State of Pennsylvania has a CEM System-based emissions monitoring program that represents a model state program in the United States.

Neither a national policy nor regulations are currently in place; however, it has been suggested that a national program be developed by guidelines similar to those of the Pennsylvania program. Details on the Pennsylvania program have been very well documented (Pennsylvania Department of Environmental Resources 1983a,b,c, 1985; Nazzaro 1986; Kerstetter 1986)).

The following are important features of the Pennsylvania program:

- Installation and Operation/Maintenance Requirements. Unlike Germany, Pennsylvania does not have a list of approved equipment. Thus, the first step in the installation of a CEM involves getting Agency approval of the equipment to be installed for monitoring purposes. This process consists of three steps. 1) Initial application has to be submitted to the department to demonstrate the capability of the system to meet all the regulatory requirements. 2) After successful verification that the equipment fulfills all the minimum requirements, the equipment must be field tested to establish its performance and accuracy under actual operating conditions. The equipment installation has to be in compliance with the Agency requirements. 3) After the field testing, a final report summarizing the results must be submitted to the Department for final approval.

how does daily average protect - 3 hr ambient standard?

does this mean emissions are exempt?

- Data Reduction and Compliance Criteria. Table 2-8 specifies the amount of valid data necessary to report an average for the specified time periods. A daily zero and span check for each analyzer is also required for data validation. Calibration checks must be made every quarter to ensure accuracy and reproducibility. Determination of compliance with SO_2 emission standards for combustion units is based on 1) a daily average limit never to be exceeded 2) a daily average limit not to be exceeded more than twice in any running 30-day period and 3) a running 30-day average limit never to be exceeded. The assessment techniques take into consideration the realities of actual operations and have built-in accommodations for soot blowing, startups, shutdowns, mailfunctions, measurement uncertainities, and daily performance. In addition, the following information is required for each daily time period: 1) the daily emission rate (if valid) in pounds SO_2/million Btu, 2) the number of valid hours of monitoring data, and 3) standardized reason codes for either excess emissions or invalid data.

TABLE 2-8. DATA REDUCTION CRITERIA FOR THE PENNSYLVANIA CEM PROGRAM

Averaging period	Criteria
One-minute	75% valid data
One-hour	75% valid data
Three-hour	2 valid one-hour averages
Daily	No more than 6 consecutive invalid one-hour averages
Running 30-day	23 valid daily averages

- Audits. These consist of Department-conducted audits and "self audits" conducted by the source. The Department audits consist of 1) a review of quarterly Excess Emissions Reports; 2) a field systems inspection, which is conducted semiannually to check the configuration, equipment condition, equipment operation, and data handling of the CEM systems; and 3) field analyzer performance audits, which consist of checking CEM System analyzer and calibration system integrity. The latter is done by studying the results of the CEM System analyzer with two different levels of calibration gas, or sealed gas cells or neutral density filters.

only for those systems which are designated as "direct-compliance"

only for NSPS. Intent already there. Appendix F designed to ensure accurate data.

Pursuing its intent of requiring sources to monitor gaseous emissions with CEM's, the EPA recently promulgated regulations that specify minimum quality assurance and quality control procedures (QA/QC) for controlling and assessing the quality of data collected by CEM's and submitted to the Agency. The requirements imposed by the regulations are similar to those required under the Pennsylvania program and have been discussed in detail by Kline (1988).

Differences In the Use of CEM Systems In the United States and Germany

The differences between the use of CEM systems in Germany and the United States are as follows:

- Germany has a consistent and well-defined National policy on CEM Systems. The U.S. EPA is still in the process of developing a National Policy.

?

national policy well defined for required monitors. Up to state to develop additional CEM requirements.

- German compliance testing is based on half-hour averages. The Pennsylvania program uses daily averages. The U.S. EPA recommends annual averages on a national level as a part of the NSPS regulations.

no way

NSPS- 3-hr D
30 day RA Data
STP - as low as 1-hr

- The German program maintains a list of approved systems, whereas the U.S. program does not. In the long run, maintaining such a list would reduce the expensive formalities and time for both the Agency and the sources. does this imply that once a monitor is certified, the entire line should be? No, case by case

- The German system requires the sources to have qualified personnel to maintain the system and to have a contract with the vendors for routine maintenance (if the facility does not have the necessary expertise). Such mandatory requirements are not found in the U.S. program. However, the frequency of calibration and checking in the United States is higher than it is in Germany.

- Agency audits of the system are performed every quarter in the United States, whereas they are performed once a year in Germany.

- The philosophy and techniques for data reduction and validation of compliance are different in the two countries. The German method seems to reduce the amount of data to be handled without compromising the quality. The use of statistical techniques in the German program also provides the sources with a better feedback system for assessing the performance of the process and taking corrective actions. ?

maybe in Pennsylvania.

in general, only Appendix F; certain state programs require quarterly and it's otherwise periodic based on monitor performance.

Bottom line:
we don't care what % of the time a source is below the standard, only when emissions are exceeded. Excess Emission criteria are well defined.

SECTION 3

EVALUATION OF EXPANDED USE OF CEM's

PEI contacted CEM vendors, sources using CEM's and enforcement agencies to get opinions regarding expanded use of CEM's for acid rain regulatory purposes. A list of questions was assembled that covered a spectrum of areas related to CEM policy issues. A summary of the questions asked are listed in Table 3-1. The questions were intended as points of discussion (rather than an objective survey) because responses in most cases required qualification. PEI telephoned the contacts and then forwarded a list of questions along with a cover letter for each contact's review. The plan was to call the study participants back to discuss the questions; however, most participants responded in writing.

As evidenced in the preceding section, the effectiveness of CEM technology for use in enforcement has been demonstrated both domestically and abroad. An EPA-sponsored study entitled "A Pilot Project to Demonstrate the Feasibility of a State Continuous Emission Monitoring System (CEMS) Regulatory Program" (1986) clearly shows that such programs, although demanding, can monitor sources effectively and enforce emissions standards in an objective manner. Some of the participants in this earlier study were purposely included in this study in order to monitor any changes in their attitude in retrospect. Other contacts were unaware of the pilot demonstration and responded on the basis of their personal experience and natural biases.

TABLE 3-1. CEM POINTS OF DISCUSSION/QUESTIONS SUMMARY

I. GENERAL INFORMATION

- Number, type, and technology/design of on site CEM's (SO_2, NO_x, and opacity)
- General cost information (analyzers, recorders, startup/installation)
- General order-to-delivery time
- Performance record (availability, reliability, percent data capture)[a]
- Application (what type of service do the CEM's see?):
- Instrument expected life:
- Vendor support (warranty period, etc.):
- Service required (e.g., scheduled calibration/maintenance-annual, monthly, daily, etc.):
- Frequency of service calls (failure rate):

II. FEELINGS ABOUT FUTURE EQUIPMENT TRENDS/ADVANCES IN CEM TECHNOLOGY:

- Reliability/availability:
- Applicability (e.g., use in areas not possible with current technology):
- User friendliness:
- Costs:

III. FEELINGS ABOUT IMPLEMENTATION ISSUES SURROUNDING EXPANDED USE OF CEM'S FOR ACID RAIN OR RELATED CONTROL PROGRAMS:

- Advantages/positive aspects:
- Disadvantages/negative aspects:
- How much data needs to be reported to the air agency?
- At what frequency should emission data be reported (between the extremes of Continuously and Annually?

(continued)

GREAT U.S.

TABLE 3-1 (continued)

- How should the frequency of reporting emission data be balanced against manpower and resource availability?
- To what extent should CEM's be integrated into an automated compliance system?
- If violoations only were reported to the air agency by an automated compliance system, how do you feel your system should be verified to ensure accurate reporting?
- How would a CEM requirement affect your existing permit conditions?

IV. TECHNICAL, COST, AND PROGRAM REQUIREMENTS FROM THE UTILITY/INDUSTRIAL PERSPECTIVE

- What would be the expected cost/availability of CEM's compared to stack test and/or parameter monitoring strategies?
- Manpower requirements (installation and operation and maintenance):
- If voluntary CEM use was chosen, to what extent would vulnerability to enforcement action be a concern?
- What would be the potential for improvements in boiler operation? (Cost savings, cost-recovery and return on investment):
- Administrative overhead/interaction with state air agency:
- Maintenance requirements:
- Relationships to existing emission requirements:

---

[a] Definitions: ? Unclear

Availability: The number of hours the CEM is available divided by the number of hours in the period (percent).

Reliability: The number of hours the CEM operated divided by the boiler operating hours in the period (percent).

Data capture: The percent of time the CEM was producing data compared to the total amount of time that it could have produced data.

22 HRS process operated vs calendar

The following subsections address the three categories individually (vendors, users, and enforcement agencies), and a summary that draws the responses together and compares the results is presented at the end of this section. The responses received from users and enforcement agencies precede the vendor input, which is in a somewhat different format.

USER RESPONSES

Qty of CEMS represented by respondees?

Utility Companies

Twenty companies were contacted. Seventeen responded to the questions, and three declined to participate in the study. The findings presented here are based on the written responses as well as the impressions obtained during telephone conversations with the utility contacts. Most of the companies were cooperative. Some were apprehensive of the overall study objectives, however, and a few refused to cooperate in any way.

The following is a list of general comments received:

define (total or per pollut)

- All respondents indicated that CEM systems showed excellent availability, reliability, and data capture (greater than 90 to 95 percent). (Some opacity monitors were reported to have greater than 99 percent reliability and availability.)

- The costs per system, including recorder/data acquisition hardware and software varied from $50,000 to $100,000.

- Reported order-to-delivery times reported varied from 1 to 5 months. One company reported an order-to-startup time of 18 months.

- Reported vendor warranty ranged from 60 days to 1 year. In general, service was considered poor and untimely. Parts were generally available, except one case in which a relatively new unit had been discontinued and parts had to be custom made by the source. Most repair work was performed by in-house personnel.

- In many cases, the frequency of service calls (failure rate) was very high early on, but as the sources assumed the responsibility for maintenance and repair work, the failure rate dropped dramatically.

Future Trends--

The utilities generally expressed the following attitudes toward the future trends of CEM's:

Beware of use of monitors) process or compliance

Bottom line: is source in compliance with limit designed to protect NAAQS or any acid rain limits

- Regarding reliability/availability, most felt that these would probably improve to close to 100 percent.

- The applicability of CEM Systems is still a problem. They often cannot be installed in environments where they might be most useful, and they are not always well suited for environments in which they are currently being used. Most indicated that current applicability needs to be improved, especially to withstand severe operating conditions with less servicing and maintenance.

- The ease with which CEM Systems can be used is expected to improve. User friendliness is still a problem, however, particularly regarding data acquisition and management systems. The average powerplant operator should be able to use the systems after minimal exposure or instruction.

- Most of the respondents believed that the costs of CEM's, especially operation and maintenance costs, would be higher in the future.

Implementation of CEM Systems--

Most respondents indicated that the use of CEM Systems offers an advantage of generating a large amount of good data, despite the fact that the data quality is very sensitive to the calibration, type of application, and frequency of maintenance. Most respondents expressed concern about the idea of using CEM Systems for automated regulatory purposes for the following reasons:

- The aforementioned sensitivity of data quality has led to erroneous readings. The systems frequently give erroneous results when the oxygen levels are low (startup situations). Thus, although no emissions problems might be present, a flag would be raised. Also, during normal operations, the emissions can vary and sometimes briefly exceed the normal limit, which creates compliance problems with the Agency.

OK

as long as EE over averaging period < EE criteria (22)

- Some respondents feared that using the data for regulatory control purposes poses several problems to the utility companies in terms of law suits, etc., as the data reported to the Agency will become public knowledge.

thats the whole idea, compliance with the standard.

this is where agency needs to define compliance format. format can then be set up on computer and reported in consistent format.

Most respondents indicated that the CEM systems represent good operating tools for control of emissions, but human analysis of the data is required to make meaningful judgments. Because of the uncertainties associated with the data, many fear that feeding such data to a computer for the checking of emissions compliance would create confusion and result in subsequent waste of manpower in paperwork and formalities.

Manpower requirements for operating CEM systems are already substantial and likely to increase. Many believe that the proposed scheme would increase the administrative load for both utilities and the EPA.

- Many companies expressed dissatisfaction with CEM vendor support.
- The life span of CEM systems varies. On newer units, it could be as long as 10 years for an SO_2 monitor and as much as 20 years on an opacity monitor.

Two respondents had no objections to the use of CEM systems for monitoring emissions compliance, and one of these two actually believes it is a good idea.

With regard to reporting the emissions to the Agency, most indicated that the quarterly reporting system (with notification of all excess emissions) was ideal (why not monthly?). Many recommended yearly stack tests and the use of CEM audits to check emissions if CEM systems were to be used. None of the companies contacted believe that using CEM systems would affect their permits. Future permits, however, might include provisions that require QA data in addition to emissions data as a condition of operation.

Summary--

There was general agreement on the following points:

- Costs (capital and operating) for CEM systems are high.
- Manpower requirements are high to maintain acceptable CEM operation.

compared to what? compliance due to installation of 80K monitor may well save 750K in damage to environment.

what are ... → DS
. Now
, Future

- Although they are considered good operational tools for controlling emissions, sources believe that CEM's should not be used to check compliance with emissions regulations. – Bottomline: monitors give accurate representation of emissions.
- Administrative work is expected to increase if CEM systems are used for checking emissions compliance. (as it should)

<u>Industrial Users</u>

Four industrial users (all pulp and paper industry) were contacted. Together they used approximately 30 CEM's. Most of these units are used for dust (opacity) monitoring and total reduced sulfur (TRS). In the industrial boiler classification few boilers are equipped with SO_2 monitors.

agreed: no federal requirement
most states cannot impose anything → federal requirement

The following is a list of general comments received:

- Monitors can provide good availability (55 to 95 percent), but extensive manpower commitment is required to obtain quality data.
- The cost of a typical CEM system runs between \$75,000 and \$100,000.
- Satisfaction with vendor support varied with the manufacturer.

Future Trends--

The industrial contacts generally expressed the following attitudes toward the future trends of CEM's.

- Newer monitors provide greater reliability/availability because conditioning systems have improved.
- Routine operation and maintenance requirements are high. Having qualified instrument people is essential to obtaining quality data.
- Concern was expressed about how the data generated are presented and reviewed. Among the sources contacted, typical requirements included <u>monthly</u> reporting.

Implementation of CEM Systems--

Several common themes were voiced by the industrial users. First, personnel costs to maintain the CEM systems are high (\$25,000 to \$40,000/yr) to produce the data required at the current level. All facilities contacted are required to monitor and report emissions on a monthly basis, with daily 24-hour averages. Some have shorter averaging times. Second, the contacts concurred that the reporting frequency should, in general, be no less than monthly and include daily averages. Shortening the averaging time or reporting period would probably overwhelm the agency's ability to analyze the data. Additional points noted included the following:

- Some CEM systems are extremely complex and additional expertise is required to determine if the data generated are of good quality.

enforcement agency should not be concerned with process-relation data - only violation information

- Reporting of only violations of standards presents a negative image. Data reported should also include the times when compliance is demonstrated. NO.

- For sources of highly variable emissions, CEM systems provide the best indicator of short-term compliance. In some processes (e.g., sulfite mills), the SO_2 monitor is essential to the process as well serving as a compliance tool. the whole intent is to design processes that don't see such wide swings in emissions

annual stack tests not appropriate

- For more stable sources, CEM systems are probably much more costly than annual stack tests. Most companies contacted are currently required to test some sources monthly to quarterly.

- For industrial users, the base of available information is not large, and they sometimes have to use utility experience in selecting a monitoring program. OK

In general, the facilities contacted have had much experience with monthly reporting because it tends to be an industry norm. They see evidence that monthly reporting is the maximum that any agency can handle. probably right.

Summary--

In summary,the following points were generally agreed upon among industrial users of CEM's:

- Vendor service is highly variable and vendor-dependent.

- The operation and maintenance of CEM systems is costly for the production of quality data. Newer equipment is more likely to maintain calibration. The more complicated the monitor system, the more costly it is.

- Although CEM data are used for compliance determination, increasing the quantity of data reported is likely to exceed agency capabilities to analyze and interpret data. The normal reporting frequency for the facilities contacted is monthly.

- Most facilities contacted monitor SO_2 as a secondary requirement (after TRS). Sulfite mills monitor SO_2 both for compliance with emission limits and for process operation, and their operation and availability are essential to their production.

ENFORCEMENT AGENCY RESPONSES

Twenty-five enforcement agency personnel were contacted. Twenty actually participated in the study, and some provided extensive information. This summary is based primarily on written responses to the questions mailed to the various State/Regional agencies.

Most contacts believe that CEM systems would allow the users a real-time feedback that could help alert the operator to potential problems. The CEM data could be used for process optimization (not goal of enforcement agency.) and trend analysis, and would allow the necessary preventive actions to be taken. They would also help the Agency to ensure continuous compliance with emissions standards and to verify compliance with short-term standards. It would also afford the Agency access to all emissions inventory data.

The following is a list of general comments received.

- Most respondents recognized the fact that CEM System have high capital and operational costs associated with them. Many respondents also recognized that QA/QC is also of some concern and, hence, the reliability of the emissions data. The use of CEM systems would require agencies to increase their manpower and upgrade the necessary hardware to be able to collect and analyze the data effectively.

not necessarily

shortcuts include summary forms
audits should be conducted by company (agency observer may need to be present)

- Typically, the Agency requires the sources to provide quarterly Excess Emission Reports (EER), the reasons for exceedances, the corrective actions initiated, total operational time of each source, and the CEM downtime. Also required are the preventive-/corrective measures taken to prevent recurrences.

- Most respondents believe that the present requirement for quarterly reports is excellent. Some believe, however, that those sources with frequent compliance problems should be required to report more frequently. Quarterly reporting should still be considered as a minimum frequency requirement. Agreed. - However, OMB feels otherwise.

Enforcement and Regulatory Impacts (Permits, etc.)

don't believe this reflects opinion of all agencies.

Our goal is not to get more data, but to get quality data that show periods when EL are exceeded

- Respondents believed that the CEM systems will help in pinpointing sources that are in violation. Proper enforcement would require the use of telemetry for a rapid data transfer. This would allow more control, would improve communications between the source and the agency, and enable the collection of greater amounts of data. Some respondents also indicated that the automated system could be programmed to prepare the quarterly reports and point out excess emissions. Some agencies approached the ideas with reluctance. The inability of agencies to purchase complete hardware/software, as well as staffing limitations places comprehensive automated systems out of their reach.

up to source to monitor, control emissions, not regulatory agencies. May improve communication between source & agency but no cases?

what the hell does this mean.

The apparent consensus was that the use of CEM systems would permit agencies to rely on spot-checks to ensure the system honesty. A few respondents, however, expressed concern about the quality of data generated (especially for SO_2 and NO_x monitoring), and, hence, the establishment of compliance based on these data. A way is needed to verify that sources comply with CEM QA/QC procedures to ensure the data are valid. Yes.

- All respondents believed that no changes in the regulations would result from the use of CEM systems. They would be used to ensure the full compliance with existing regulations. Also, any changes in regulations would require a lengthy process of hearings, SIP revisions, and public relations campaigns. Suggestions that averaging periods might be shortened would be highly controversial. The implementation of such changes would be on a case-by-case basis during permit negotiations rather than through higher level hearings and rule-making activities.

depends on goal of legislation. Some existing sources are the greatest emitters and therefore are prime candidates for CEMS.

The use of CEM's should not entail a change in the existing permits. Moreover, most RCRA facilities and other waste incinerators use CEM systems as a part of permit requirements. Some agencies suggested that their permitting systems were sufficiently advanced that future permitting would not be likely to change significantly.

- Most respondents expressed belief that the States would specify CEM systems more extensively in the future to collect data, to check compliance, and to monitor facilities that are frequent violators. Some suggested their state would only expand efforts in this area if encouraged to do so by the U.S. EPA and had sufficient demonstrated data indicating that CEM programs are viable tools for assessing continuous compliance. Bullshit! already established.

only if a federal requirement

The consensus was that most facilities would not use CEM systems on a voluntary basis; however, many facilities ~~might have~~ to install them because of permit requirements or as a bargaining item for facilities located close to cities. should be a thing of the past — to ofelme

- Most agencies will require additional manpower just to review CEM data. Additional manpower will also be required ~~for~~ installation and certification activities. The manpower projection varied from one to eight full-time employees. Virtually all agencies contacted projected staffing increases and the need to upgrade computer hardware and software.

- Most agencies expect the administrative burden to increase in terms of paper work, enforcement, data analysis, etc. A minimal increase would require one engineer half-time. not necessarily, could be experienced technician

Summary

The following summarizes the general enforcement agency responses.

Enforcement Difficulty--

The responses indicated the following problems will have to be solved in the enforcement of CEM programs:

- Agency staffing will need to be increased to review and analyze the data. depends on scope of legislation

- wrong — Regulations will have to be enacted to define compliance standards with respect to CEM technology. ?

- wrong — No court precedence exists for CEM compliance. ?

- wrong — The Agency does not appear to have a well-defined enforcement policy. ?

- wrong — Some question the reliability of CEM data. They believe that it would not be possible to prove noncompliance based on CEM data because no reference method for SO_2 and NO_x includes CEM's. NO!

Smelter Not true. Subpart Da requires CEM. also ~~

Efficiency of CEM System Usage--

Some difference of opinion exists in this area. The two schools of thought on this issue were as follows:

- Some respondents believed that no significant improvement in the emissions compliance would be achieved by using the CEM's. With a very few exceptions, most facilities are believed to meet the emissions ~~standards~~. The non-compliance in a few cases was due to fugitive emissions for which CEM's would be of little value.

- Many other respondents believed that the CEM's would help in effectively enforcing the emissions compliance and in pinpointing frequent violators. Also, automated CEM programs can reduce the reliance on annual stack tests in some cases. A good automated CEM system can allow agencies to respond more quickly and follow up on problems more effectively. AVOID "SHOTGUN" INSPECT'S

Future Trends--

Regarding future trends, most believed that the reliability and availability of CEM systems ~~should~~ would improve. Many expect more applications for CEM's (HCl, H_2S, etc.) in the future. Some expect costs to increase, whereas others suggested improving technology and electronics would gradually reduce costs. Some agencies voiced an interest in CEM development in air toxics.

VENDOR RESPONSES

Fourteen CEM suppliers were contacted. All of them were cooperative, and all participated, at least to some extent. A detailed summary of information obtained from different CEM vendors is provided in Appendix A of this report, which is a copy of the interim report for the project entitled "Review of Manufacturers Data on Continuous Emission Monitors for SO_2, NO_x, and Opacity." This section constitutes a summary of the vendor information in light of the response obtained from the sources and the regulating agencies.

Aspire

The following is a list of general comments received:

- The cost of the entire system varies from approximately \$60,000 to \$100,000.
- Order-to-delivery varied from 1 to 4 months. In some cases the delivery period was as long as 13 to 14 months.
- Most vendors reported a warranty period of about a year. Some reported warranty periods greater than a year. Others offered different warranties on different system components.
- All vendors reported greater than 90 percent data capture; however, no information was furnished regarding the availability and reliability because most believed it depends on the application, the type of maintenance and care taken at the facility, etc.

Technical Information

One of the major concerns expressed unanimously by the industry (sources) and a few agencies was the quality of the data generated by the CEM systems. However, specific information/clarification addressing this concern was not available from the vendors, however. Also, it is highly unlikely the CEM vendors would critique their own systems, especially when there is great potential for expanding their market share.

The information on types of CEM systems available in the market, their working mechanism, advantages, and disadvantages are summarized in Appendix A. The salient features that have a relationship to the data quality are presented here:

- Range of Instrument. Varies. SO_2/NOx Could be anywhere from 0 to 1000 ppms. Apparently some instruments can measure concentrations in the ppb ranges.
- Temperature. Most CEM systems appear to operate in the range of 100° to 150°F, but some units can operate at higher temperatures (300° to 800°F).

(ambient or in-stack?

- Other parameters.

Zero drift	=	0.5 to 1 percent/7 days
Span drift	=	About 1 to 4 percent/7 days
Response time	=	Varies; 2 to 200 seconds
Precision/ accuracy	=	90 percent of full-scale ± 1 percent
Repeatability	=	About 0.2 percent of scale

Future Trends

Almost all vendors expect to have CEM systems suitable for more applications in the future. Extensive research is reportedly being done to improve existing equipment to minimize the drifts, to increase sensitivity and accuracy, and to make it more robust so that it can withstand severe operating conditions. A certain ambivalence about the future seems to exist, however, especially because most believe that the future market will depend on government regulations. Most vendors believe that the costs would remain stable; however, a few expect costs to drop as a result of technological advances.

Most of the views expressed by the users and by some Agencies have been corroborated by the vendors; however, the vendors believe that their equipment is reliable and ideal for controlling and monitoring emissions, and expect the performance to improve with advances in the technology. The future market for this industry will depend greatly on regulations enacted by the EPA.

SUMMARY OF ALL CATEGORY RESPONSES

Because responses varied greatly among categories of respondents, it was not possible to make a point-by-point comparison of opinions. Some questions that were appropriate for one group did not apply to one or both of the others, and each group did not interpret the questions in the same way. All three groups are aware that the cost of CEM systems is high. As one would expect, the cost concern was greater among utility/industrial contacts. All three groups were aware of the manpower requirement to operate and maintain CEM systems. This was identified by both utility/industrial and enforcement agency contacts as an important concern that will become more significant in the future. Both acknowledged the need for staffing increases by agencies as well. All three groups reported that CEM's can operate at high availabilities and reliabilities with adequate (sources suggest exhaustive) O&M procedures. Sources are uncomfortable with propositions that promote a heavy direct reliance on CEM's for compliance, but their use as an indicator of compliance accompanied by human input/qualification was not objectionable. All three groups generally agree that some sort of CEM-supported policy could be effective in emissions monitoring and control. There was considerable variance in the degree to which respondees believed (even within the agency group) CEM system readings should be accepted in a compliance determination.

? d , CEM = CI

SECTION 4

RECOMMENDATIONS AND CONCLUSIONS

Although industry may be apprehensive about using CEM systems, there is good reason to expect that problems can be averted and a workable policy can be implemented that both industry and enforcement agencies will be comfortable with. The following points summarize recommendations and conclusions that support the development of an effective CEM policy.

- National Policy Issue. Currently a well-defined national policy is lacking on the use of CEM's for checking compliance and enforcement. Current policies are not uniform; i.e., new and existing sources are subject to different standards and compliance requirements. This is a sore point with many sources, and many regard the agencies' policies as unfair. In addition, many agencies and sources believe that the current data requirements are redundant. The EPA needs to formulate policy that will reduce data handling, without compromising the quality.

CA Req'mts

- Quality of the Data Obtained From CEM Systems. Much apprehension exists about the accuracy and quality of data generated by CEM Systems. Some recent studies carried out by the EPA, however, suggest that with proper care and maintenance, CEM systems give fairly reliable data. More studies and field surveys of actual operating CEM Systems may be required to establish the performance capabilities. The technology has been used successfully abroad to verify continuous compliance. Therefore, it is important to establish if the quality of U.S. instruments with these used abroad.

no!

- High Capital and Operating Costs. Although this is a valid concern, as the technology is further developed, these costs could come down. In the long run, installing CEM Systems may 1) reduce costs by eliminating the need to do expensive emissions testing every quarter, 2) gain public and agency good will for the company, 3) help the source to reduce emissions and to operate the process optimally, and 4) reduce the paperwork required to establish compliance. or

NOT necessarily?

why req'd?

not required now,

CC Req's HOW ELSE can CC be eliminated/evaluated?

legal legwork

not our goal

- Increased Administrative Load for the Source and the Agency. The way the program is currently envisioned, some increase could occur in the specialized manpower requirement, especially for ~~reporting~~ & CEMS and ~~analyzing the data~~. By using telemetry, however, the Agency can reduce the frequency at which the sources have to file emissions reports, which would reduce the paperwork and the official formalities. Also, as the program develops, the Agency can use an approach similar to that used in Germany, wherein the amount of data that needs to be handled is considerably reduced.

what are agencies going to do with mounds of complex data

- Lack of Legal Precedents on CEM Systems in Courts. This should not be a problem in view of the increased reliability and accuracy of CEM Systems. I dont know what this means. Tons of actions are underway.

PR only.

- Guidance Document. A National policy/guidance document of Federal EPA recommendations for establishing a State CEMS plan similar to that existing in Pennsylvania could be prepared. Such a document would include such items as projected staffing and computer needs of various implementation levels. GOOD

- Need for Further Study. There is a need for further study on both the technology and enforcement of CEM regulations in Japan and European countries.

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APPENDIX A

REVIEW OF MANUFACTURERS' DATA
ON CONTINUOUS EMISSION MONITORS
FOR SO_2, NO_x, AND OPACITY

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Introduction

The purpose of Task 1 of the CEM STAR project is to determine the state of the art of continuous emissions monitoring systems (CEMS). A list of major manufacturers was developed using the Thomas Register, Pollution Equipment News, the literature and other manufacturers. These manufacturers were surveyed and their responses (as well as data from other sources) were summarized to determine the types of monitors in use today, their costs, applications, and specifications. This has been done for CEMS which monitor sulfur dioxide, oxides of nitrogen, and particulate matter (PM). The information summarized includes type of monitoring technique, manufacturer, sensitivity, temperature range, estimated percent data capture, cost, expected lifetime, warranty, delivery time, and applications. Tables 1 through 3 summarize this information for SO_2, NO_x, and PM, respectively and a description of each type of CEM evaluated is presented below.

Nondispersive Infrared Monitors

Non-dispersive infrared (NDIR) technology is one of the most popular techniques available. It is predominantly used to analyze SO_2 emissions but can also be used for NO. However, it can not analyze NO_2 emissions. Major manufacturers of this primarily extractive technique for SO_2 include Westinghouse, Horiba, Datatest, and Lear Siegler, Inc. These models can have different sensitivity ranges according to the consumers needs, varying from a minimum of 10 to 20 ppm to a maximum of 1000 ppm. Westinghouse has a model which can measure up to 100 volume percent. This model can also be used for NO. Water vapor interference is a problem with this technique, so a good conditioning system must be used to rid the gases of any water present. The temperature of the gas must also be lowered to 125-150°F before entering the analyzer.[1]

Most manufacturers of this type did not want to comment on reliability or availability of their equipment, due to the dependence of these factors on the source of emissions and the care of the consumer. Westinghouse, however, said that they have more than a 90 percent data capture rate on their model. Literature provided by Westinghouse gave zero and span drifts of 1 percent per week, repeatability of 0.5 percent of full scale, and an adjustable response time of 1.5, 4.5, or 11 seconds for 90 percent of full scale. The

San Francisco Bay Area Air Quality Management District (BAAQMD) reported a value of 99 percent for the data capture rate of the NDIR continuous emissions monitors in their area.[2]

All of the above manufacturers offer a one year warranty. Equipment costs of these monitors (analyzer and recorder) varied from $5,200 for a Westinghouse to $35,000 for a Datatest model. Installed costs for complete systems ranged from $60,000 - $80,000 depending on the source of emissions and included data acquisition system. Applications for this technique included emissions from boiler and utility stacks, process control, incinerators, and emissions from the pulp and paper industry.

Pulsed Fluorescence Monitors

Pulsed fluorescence is an extractive technique for measuring sulfur dioxide emissions which involves molecules absorbing ultraviolet light and emitting fluorescence. This technique can measure lower concentrations than can be measured using NDIR. Interference problems still occur with water vapor and also with carbon dioxide. Pulsed fluoroscence monitors cost less than NDIR monitors, with a range of $8000 - $8500 for equipment costs.[1]

Monitor Labs, Columbia Scientific Industries and Thermo Electron Corporation manufacture pulsed fluorescence monitors. Each model can vary in sensitivity range with Columbia Scientific offering two ranges: 0-250 ppb and 0-10 ppm. Temperatures that the analyzer can withstand vary greatly. Thermo Electron's model has a maximum temperature is 300°F and Columbia Scientific's model, 80°F.

All of these manufacturers reported a data capture rate of over 90 percent, with Thermo Electron claiming 97-100 percent data capture. Monitor Labs gave data in their brochure of a zero drift of 3 ppb/7 days and 2 ppb/24 hours, a span drift of 4 percent/7 days and less than 0.5 percent/24 hours, a response time of 260 seconds to reach 90 percent of full scale, and a precision of 0.001 ppm.

All manufacturers offered a 1 year warranty and expect the CEM to last at least 10 years, dependent upon the application. Applications are much the same as for NDIR, utilities, incinerators, and the pulp and paper industry.

Nondispersive Ultraviolet Monitors

DuPont and Western Research manufacture CEMs using another extractive technique called non-dispersive ultraviolet (NDUV). KVB who sells monitors, but does not manufacture them praised this type of monitor. There is much less interference in the UV spectrum than in the IR spectrum. DuPont's model will handle both SO_2 and NO_x, but Western Research's only measures SO_2. According to KVB, the Western Research model is more reliable than the DuPont model because it measures on two wavelengths. The sensitivity range for DuPont is 0-100 ppm, but Western Research measures 0-500 ppm. The DuPont model has been criticized in the literature, because its conditioning system did not perform well, and should not be used for wet gases.[1,3]

No data were available on percent data capture. The specifications for the Western Research CEM are less than 1 percent of full scale drift, 0.25 percent of scale reproducibility, and an accuracy of 1 percent of full-scale. It costs $80,000 for a single point system and comes with a 1 year warranty. Applications for this technique include utilities, chemical plants, refineries, and the cement industry.

Flame Photometric Monitors

The Meloy Model SA28SE using a flame photometric device is another extractive system by Columbia Scientific Industries. This model is used for ambient monitoring as opposed to source monitoring and is designed for very low concentrations of SO_2 with ranges of 0-50 ppb and 0-1 ppm. Its equipment cost is $9000 and it has a data capture rate of over 90 percent. A zero drift of 2 ppb/12 hours and 5 ppb/24 hours, and a response time of 0.5 to 5 minutes for 95 percent of scale can be obtained with this monitor.

Electrochemical Monitors

Another extractive technique used for low concentrations and is best suited for indoor pollution is electrochemical. Interscan and Sensidyne are two manufacturers of this equipment which will measure both SO_2 and NO_x. Sensitivity ranges from 0-100 ppm and the monitors cost $2500. Although no manufacturer gave data on percent data capture, a survey in the literature reported 98 percent data capture rate in the California South Coast Air Quality Management District (SCAQMD).[2]

Chemiluminescence Monitors - NO_x

Chemiluminescence is an extractive technique used to measure NO_x emissions. Manufacturers of this type of CEM include Thermo Electron, Monitor labs, Horiba, Datatest, Columbia Scientific Industries, and Lear Siegler, Inc. The Thermo Electron Model 10 or the Monitor Labs Model 8840 come highly recommended.[1]

Monitor Labs gives specifications for their monitor as zero drift of 0.4 percent/24 hours and 0.5 percent/7 days, span drift of ±1 percent/24 hours and 2 percent/7 days, a response time for 95 percent of 3 minutes, and a precision of ±1 percent.

Thermo Electron model has a drift of ±1 percent/24 hours, repeatability of 0.2 percent, a response time of 0.7 seconds for 90 percent of full scale and an accuracy of ±1 percent of full scale.

Over 90 percent data capture rates were given with Thermo Electron reporting greater than 97 percent. SCAQMD and Texas Air Control Board (TACB) reported 99 percent for the chemiluminescent CEMS in their areas.[2]

The costs of these analyzers varies greatly from $8000 to $35,000. An entire system can cost anywhere from $60,000 to $100,000. All manufacturers offer at least a one year warranty with Monitor Labs offering a two year warranty. These monitors can be used for all types of stack emissions.

In Situ Monitors

Westinghouse, Lear Siegler, and Dynatron each make in-situ models that utilize different techniques. Dynatron uses non-dispersive infrared to monitor SO_2 and NO_x. This monitor has sensitivity ranges of 0-250 ppm and 0-500 ppm for SO_2 and NO_x respectively. It is automatically calibrated, can reach a stack temperature of 800°F, has an adjustable response time of 1-999 sec, repeatability of ±1 percent, a drift of 1 percent full scale for 30 days, and an accuracy of ±2 percent full scale. No information was given on cost, but a two year warranty came with this model.

Westinghouse's in-situ CEM uses an electrolytic probe. A variety of concentration ranges from 10-1000 ppm sulfur dioxide and temperatures of 1500°F can be handled with this monitor. Ninety percent data capture is possible with this model and it costs $80,000 for a complete system with a 1 year negotiable warranty. Applications include process control or monitoring stack emissions for compliance. Utilities and fluidized catalytic cracking units are two examples.

Lear Siegler's in-situ model uses a second derivative ultraviolet technique to measure box NO_x and SO_2. This model has equipment costs of $40,000 with a 1 year warranty. In a literature survey, the California South Coast Air Quality Management District reports a 96 percent data capture rate, the San Francisco Bay Area Air Quality Management District a 97 percent rate, and the Texas Air Control Board a 89 percent for CEMS using this technique.[2]

Opacity Monitoring

Opacity monitors come in two types: single pass and double pass. Single pass monitors have a light source on one side of a stack and a receiving unit on the other to measure transmittance. Double pass monitors have the light source and receiving unit on one side of the stack with a mirror on the other to reflect the light back across the stack to the receiving unit. Costs depend on the stack diameter and source of emissions. A typical single pass monitor could cost $3000, while a double pass would cost around $20,000. The Texas Air Control Board (TACB) reported 97 percent data capture on the 11 models in their area. Of these 11 models, 175 malfunctions occurred in an 18 month period with an average downtime of 16 hours. Seventy-four (74) percent of the malfunctions were due to data processing equipment.[2]

For NO_x and SO_2 extractive models in the SCAQMD, BAAQMD and TACB areas, 519 malfunctions occurred within 41 models, with an average downtime of 12 hours. Seventy two in situ models had 1054 recorded malfunctions with an average downtime of 39 hours.[2]

Future Trends in CEMs

Manufacturers representatives were asked their opinion on the future of CEMs. It was believed that the applications for CEMS would increase in the next several years. Much research is going on to improve the available equipment so that less drift occurs and more sensitivity is achieved. Columbia Scientific Industries is currently trying to develop a monitor for use in the pulp and paper industry. Such a monitor would be subject to a very dirty environment and would require good conditioning equipment. Westinghouse and Thermo Electron expect CEMs to be used more often in incinerators.

Westinghouse is doing significant amount of research and has a new product on the market for SO_2. Several manufacturers were not sure what to expect, but felt that the market would depend on government regulations. Most representatives felt that the costs would remain stable although some expected a slight decrease with new technology.

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TABLE I. SUMMARY OF MANUFACTURERS' DATA ON CEM'S FOR SO_2 PROCESSES

Technique	Manufacturer	Sensitivity	Temperature range	% Data capture	Cost	Lifetime	Warranty	Delivery time	Applications
NDIR	Westinghouse	10-1000 ppm	<1800°F (stack)	90+	$5,200[a]	NAV*	1 year	<3 months	Industrial uses Monitor stack emissions
NDIR	Syconex (In-situ)	2-7 microns	0-1000°F (stack)	NAV	$19,000-$22,000[a]	NAV	1 year	2-2½ months	Combustion efficiency Compliance with EPA standards
NDIR	Horiba	Varies	-15°C-110°F	NAV	$15,000+[a] $100,000 + for entire system[b]	10+ years	1 year	3-6 months	Power, paper & pulp incineration
NDIR	Data test	Varies in range 0-500 ppm min and max	<125-150°	NAV	$25,000-$40,000 $80,000+ for entire system[b]	10-15 years	1 year	2-3 months	Utility stack emissions
NDIR	Lear Siegler, Inc.	Varies	-20-110°F	NAV	$60,000 includes analyzer and controls	30 years	1 year	2½-3 months	Stack emissions
NDIR	Enviroplan (buys from others)	Varies	<130°F for analyzer	>90%	$29,000 one gas[a]	Probe 7 yrs Analyzer >10 yrs	1 yr	13-18 months	Industrial stack emissions, waste to energy systems
IR	Dynatron (in-situ)	ppm to percent varies	800°F max	NAV	NAV	Varies	2 years	Varies	Stack emissions
Electrolytic Probe	Westinghouse (in-situ)	10-1000 ppm (various ranges)	1500°F	>90%	$80,000+ for system[b]	NAV	1 year (negotiated)	<3 months	Stack emissions, process control, fluidized cat-cracking
2nd Derivative Ultraviolet	Lear Siegler (in-situ)	Varies	NAV	NAV	$40,000[a]	30 years	1 year	1 month	Stack emissions
Pulsed fluourescent	Monitor labs	0.001 ppm minimum	5-40°C	92-93%	$8500[a]	8-10 years	2 years	<3 months	Ambient, stack emissions
Pulsed fluorescent	Thermo Electron	ppb	300°F max	97-100%	$8500[a] 60,000+ system[b]	10+ years	1 year	3 months	Process control, stack emissions

(continued)

TABLE I (continued)

Technique	Manufacturer	Sensitivity	Temperature range	% Data capture	Cost	Lifetime	Warranty	Delivery time	Applications
NDUV	DuPont model 400	0-100 ppm	-20-120°F	NAV	NAV	NAV	1 year	NAV	Plant stacks to meet regulations, chemical plants, refineries, etc.
NDUV	Western Research (from KVB)	0-500 ppm	NAV	>90%	$80,000 single pt. system[b]	10 years	1 year	3 months	Stack emissions from utilities, cement industry
Pulsed fluorescence	Columbia Scientific SA-700	Varies Low 0-250 ppb High 0-1 ppm	70-80°F 1100°F probe	>90%	$8000[a]	10-15 yrs Probe: 1 yr	NAV	2-3 months	Coal-fired applications, venting of landfill gas (causes problems) not for pulp and paper
Flame photometric	Columbia Scientific SA-285-E	Varies Low 0-50 ppb High 0-1 ppm	70-80°F 1100°F	>90%	$9000[a]	10-15 yrs Probe: 1 yr	NAV	2-3 months	For low concentrations - ambient monitoring
Electro-Chemical	Interscan	Varies Min 0-1 Max 0-50 ppm	NAV	NAV	Analyzer 2500, Recorder $500-$1400	5 years	Analyzer 1 yr Probe 6 mths	Varies	Indoor pollution, for health and safety of workers, not stacks
Electro-Chemical	Sensidyne	0-10 ppm or 0-100 ppm	14°-122°F	NAV	$3050[a]	3 years for sensor	Analyzer 1 yr Probe 90 days	1-1½ months	Indoor pollution

*NAV means data is not available.

[a] Analyzer and recorder only.

[b] Installed cost of analyzer, recorder, and data acquisition system.

TABLE II. SUMMARY OF MANUFACTURERS' DATA ON CEM'S FOR NO_x PROCESSES

Technique	Manufacturer	Sensitivity	Temperature range	% Data Capture	Cost	Lifetime	Warranty	Delivery time	Applications
Chemilum-inescence	Thermo Electron Model 10	As low as 1 ppb	~ 300°F max	97-100%	$8,500[a]	10+ yrs	1 year	3 months	Process control; stack emissions
Chemilum-inescence	Monitor Labs Model 8840	2 ppb minimum	5°C-40°C	92-93%	$8,100[a]	8-10 yrs	2 years	<3 months	Mainly ambient, some adapted for stacks
Chemilum-inescence	Horiba	Varies	-15°C-110°F	NAV	$15,000+ $100,000+ for entire system[b]	10+ yrs	1 years	3-6 months	Stack emissions from power, paper, and pulp incineration
Chemilum-inescence	Data test	Varies in ranges 0-500 ppm min and max	<125-150	NAV	$35,000-$40,000,[a] $80,000+ for entire system[a]	10 years	1 years	2-3 months	Utility stack emissions
Chemilum-inescence	Columbia Scientific Industries	0-5 ppm Model 1000 0-1000 ppm Model NA-510	70-80°F Probes 1100°F Stack	90%+	$8000[a]	10-15 yrs probe ~ 1 year	NAV	2-3 months	Stack emissions from coal-fired applications, cement kilns, not for pulp and paper
Chemilum-inescence	Lear Siegler, Inc.	Varies	-20-110°F	NAV	$60,000 (analyzer and control)	30 years	1 year	2½-3 months	Stack emissions
Electro-Chemical	Interscan	1152 0-2/0-10 1154 0-10/0-50 ppm	NAV	NAV	Analyzer $2500, Recorder $567-$1400	5 years	Analyzer 1 yr Probe 6 mths	Varies	Indoor pollution, for workers safety
Electro-Chemical	Sensidyne	0-10 ppm or 0-100 ppm	14°-122°F	NAV	$1200 sensor $1800 analyzer	3 years (sensor)	1 year elections 90 days sensor	1-1½ months	Indoor pollution
NDIR	Syconex (in-situ)	2-7 microns	0-1000°F (stack)	NAV	$19,000-22,000[a]	NAV	1 year	2-3 months	Combustion efficiency
NDIR	Enviroplan (Buys from others, does not manuf.)	Varies	<130°F in analyzer	>90%	$29,000 total for 1 gas[b]	Probe 7 yrs Analyzer > 10 yrs	1 yr	13-18 months	Stack emissions, waste to energy operations

(continued)

TABLE II (continued)

Technique	Manufacturer	Sensitivity	Temperature range	% Data Capture	Cost	Lifetime	Warranty	Delivery time	Applications
IR	Dynatron (in-situ)	ppm to % varies	800°F max	NAV	NAV	Varies	2 years	Varies	Stack emissions
NDIR	Westinghouse (Maihak)	20 ppm-100 vol. %	32-105°F 1800°F (stack probe)	>90%	$5200[a]	NAV	1 year (negotiated)	<3 mths	Process control, boiler stacks, air pollution control
2nd Derivative Ultraviolet	Lear Siegler (in-situ)	Varies	NAV	NAV	$40,000[a]	30 yrs	1 year	1 month	Stack emissions
NDUV	DuPont	0-200 ppm	-20-120°F	NAV	NAV	NAV	1 year	NAV	Plant stacks at chemical plants and refineries, EPA Regulations

*NAV means data is not available.

[a] Analyzer and recorder only.

[b] Installed cost of analyzer, recorder, and data acquisition system.

TABLE III. SUMMARY OF MANUFACTURERS' DATA FOR OPACITY

Technique	Manufacturer	Sensitivity	Temperature range	% Data capture	Cost	Lifetime	Warranty	Delivery time	Applications
Double pass	Dynatron	0-100%	750°F max 30-150°F microproc.	NAV	NAV	Varies	3 years on light source	Varies	Stack emissions
Double pass	Syconex		0-1000°F	NAV	$19,000-22,000[a]	NAV	1 year	2-2½ months	Compliance with EPA standards
Single and double pass	Data test	0-100%	NAV	NAV	$995-20,000[a]	10-15 years	1 year	2-3 months	Stack emissions
Single pass	Wager	0-100% 1% increments	0-50°C	NAV	$2978 total[b]	NAV	1 year	1½-2 months	Incinerators, baghouses, stack emissions
Double pass	Lear Siegler	NAV	-20-110°F	NAV	$20,000-24,000 (analyzer and control)	30 years	1 year	2½-3 months	Stack emissions

*NAV means data is not available.

[a] Analyzer and recorder only.

[b] Installed cost of analyzer, recorder, and data acquisition system.